THE

KANSAS UNIVERSITY SCIENCE BULLETIN.

Vol. I, No. 9—September 1902.
(Whole Series, Vol. XI, No. 9.)

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PUBLISHED BY THE UNIVERSITY,

Lawrence, Kan.

Price of this number, 30 cents.

Entered at the post-office in Lawrence as second-class matter.

KANSAS UNIVERSITY SCIENCE BULLETIN.

VOL. I, No. 9. SEPTEMBER, 1902. { WHOLE SERIES VOL. XI, No. 9.

RESTORATION OF DOLICHORHYNCHOPS OSBORNI, A NEW CRETACEOUS PLESIOSAUR.

BY S. W. WILLISTON.

With Plate XI.

No less than twenty-seven species and fourteen genera of plesiosaurs have been described from the mesozoic deposits of North America, with but few exceptions based upon very scanty material. The earliest of these are from the Baptanodon beds of the Jurasssic of Wyoming, and the latest is reputed to be from the Laramie Cretaceous. Every intervening epoch, unless it be the Dakota, has furnished one or more species, but, notwithstanding all this great diversity and wide geological range, we have hitherto known but little concerning this order of reptiles in America—less perhaps than of any other equally extensive group. Enough, however, is already known to make it certain that we have to do with a great diversity of types. The following is a preliminary list of the American forms of this order hitherto described:

Plesiosaurus.

lockwoodi Cope, Ext. Batrach., etc., 1869, 40. Cretaceous, New Jersey.

brevifemur Cope, Cret. Vert. 256. Cretaceous, New Jersey.

gulo Cope, Proc. Acad. Nat. Sci. Phil., 1872, 128. Niobrara Cretaceous, Kansas.

occiduus Leidy, Proc. Acad. Nat. Sci. Phil., 1870, 74; Rep. Geol. Surv. Terr., 1873, I, 345, pl. xv, ff. 11–13; Cope, Cret. Vert. Laramie Cretaceous, Dakota.

gouldii Williston, Kans. Univ. Quart, VI, 57. Comanche Cretaceous, Kansas.

mudgei Cragin, Fifth Publ. Colo. College Sci., 1894. Comanche Cretaceous, Kansas.

shirleyensis Knight, Amer. Jour. Sci., X, 1900, 115. Baptanodon beds, Jurassic, Wyoming.

Discosaurus Leidy, Proc. Acad. Nat. Sci. Phil., 1851, 326 (1852).

vetustus Leidy, l. c.; Cope, Ext. Batrach. Alabama.

Brimosaurus Leidy, Proc. Acad. Nat. Sci. Phil., 1854, 73.

grandis Leidy, l. c., pl., I, ff. 1–3; Cope, Ext. Batrach., 1869, 43. Clark county, Arkansas.

Polycotylus Cope, Ext. Batrach., 1869, 39.

latipinnis Cope, l. c.; Cret. Vert. 60. Niobrara Cretaceous, Kansas.

Cimoliasaurus Leidy, Proc. Acad. Nat. Sci. Phil., 1851, 325 (1852).

magnus Leidy, l. c.; ibid., 1854, 72, pl. II, ff. 4–6; Cret. Rept., 1865, 25, pl. V, ff. 13–19, pl. VI; Cope, Ext. Batrach., 1869, 42; Lydekker, Cat. Fos. Rept., II, 211. Cretaceous, New Jersey.

planior Leidy, Proc. Acad. Nat. Sci. Phil., 1870, 22. Cretaceous, New Jersey.

snowii Williston, Trans. Kans. Acad. Sci., 1891; Cope, Proc. Amer. Phil. Soc., 1894, 199. Niobrara Cretaceous, Kansas.

laramiensis Knight, Amer. Jour. Sci., X, 1900. Baptanodon beds, Jurassic, Wyoming.

Uronautes Cope, Proc. Acad. Nat. Sci. Phil., 1876, 345.

cetiformis Cope, l. c., 346. Fort Pierre Cretaceous, Montana.

Embaphias Cope, Proc. Amer. Phil. Soc., 1894, 112.

circulosus Cope, l. c., 112. Fox Hills Cretaceous, South Dakota.

Oligosimus Leidy, Proc. Acad. Nat. Sci. Phil., 1872, 39 (1873).

grandævus Leidy, l. c., 40. Green River, Wyoming (Cretaceous).

Orophosaurus Cope, Amer. Nat., 1887, 564.

pauciporus Cope, l. c. Fox Hills Cretaceous, New Mexico.

Piptomerus Cope, Amer. Nat., 1887, 564.

megaloporus Cope, l. c. Fox Hills Cretaceous, New Mexico.

microporus Cope, l. c. Ibid.

hexagonus Cope, l. c. Ibid.

Megalneusaurus Knight, Amer. Jour. Sci., V, 1898, 375.

rex Knight, Science, 1895, 449 (*Cimoliasaurus*). Jurassic, Wyoming.

Trinacromerum Cragin, Amer. Geologist, Dec. 1888.

bentonianum Cragin, l. c.; ibid., 1891, 171. Benton Cretaceous, Kansas.

Elasmosaurus Cope, Notes of Geology Ul Pacific, Leconte, 1868.

platyurus Cope, l. c., 68; Ext. Batrach., 1869, 44; Hayden, Geol. Surv. Terr., 1870, 393. Fort Pierre Cretaceous, Kansas.

serpentinus Cope, Bull, U. S. Geol. Surv., III, 578, 1877. Nebraska Cretaceous, Nebraska.

intermedius Cope, Proc. Amer. Phil. Soc., 1894, 112. Fort Pierre Cretaceous, South Dakota.

orientalis Leidy, Proc. Acad. Nat. Sci. Phil., 1870, 22.

(*Discosaurus*) Cope, Ext. Batrach., 1869, 55. Cretaceous, New Jersey.

Pantosaurus Marsh, Rep. Geol. Congress, 1891, 155; Amer. Jour. Sci., 1895, 408; ibid., XLII, 1892, 388 (*Parasaurus*).

st ratus Marsh, Amer. Jour. Sci., XLII, 338 (1891); ibid., I, 406, 1895, ff. Baptanodon beds, Jurassic, Wyoming.

These known American plesiosaurs vary in length from that of *Dolichorhynchops*, described in the present paper, to that of *Megalneusaurus rex* Knight, or of one whose remains are in the University of Kansas museum, forty or more feet in length.

The specimen of *Dolichorhynchops osborni* herewith figured was collected in 1901 in the chalk of western Kansas by Mr. Charles Sternberg. When received at the museum the skeleton was almost wholly contained in a large chalk slab, with all the bones disassociated and entangled together closely. Owing to their extreme softness, a characteristic of plesiosaur bones in general, the labor of removing the different parts of the skeleton and hardening them so that they could be handled has been exceedingly slow and painful. The task of removing and mounting the bones has required the skilled labor of Mr. Martin, the preparator, the larger part of a year, under my constant supervision. The skeleton as now mounted is an example of great skill on Mr. Martin's part and of much study.

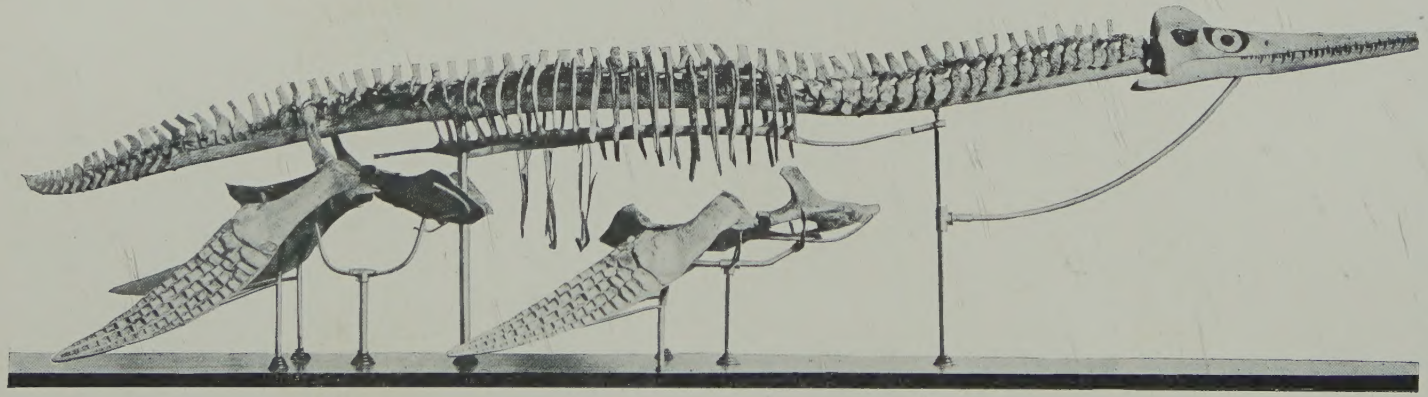
As mounted there is little conjecture. It is possible that some of the vertebræ may be missing, but I do not think so, unless a very few from the tail. Three or four vertebræ and a few ribs were so badly decomposed that they have been modeled in plaster, and a number of the dorsal spines could not be recovered. There is also doubt about the proper length of some of the posterior ribs. The skull, after its complete removal from the chalk, was found to be so very fragile that it was not thought to be expedient to mount it with the skeleton. A model, therefore, has been made, under my careful supervision, and mounted in its stead. The many bones of the limbs were so intermingled that only a careful study permitted their collocation, a task, aided, however, by a nearly complete paddle of an allied form, about which there was less doubt. There are nineteen vertebræ in the neck, thirty in the trunk, and twenty-five preserved in the tail, which tapers very abruptly at the extremity. There may have been a few more vertebræ in the tail, though this is doubtful. The skeleton, as mounted, is just ten feet in length.

There are not a few new or strange characters presented by this skeleton, especially in the skull, nearly all of the details of which have been made out, such as the presence of two separate and disconnected supraoccipital bones, peculiar frontal

bones, the presence of a quadratojugal, and of a well-ossified sclerotic ring, etc. The pectoral girdle, which, with the pelvic girdle, is marvelously complete and undistorted, has a large interclavicular foramen, never before observed in these animals, though present in other forms. A full description of the skeleton, with illustrations, is already prepared for publication.

It is possible that the present species may prove to belong to some one of the previously described genera, but from a prolonged study of the descriptions extant, and of the nine or ten species actually known to me, I do not think so. I have therefore given it the name of *Dolichorhynchops osborni* in honor of Prof. H. F. Osborn, of Columbia University, the well-known paleontologist.

PLATE XI.



Restoration of *Dolichorhynchops osborni* Willist. One-sixteenth natural size.

NOTES ON SOME NEW OR LITTLE-KNOWN EXTINCT REPTILES.

BY S. W. WILLISTON.

With Plates XII and XIII.

Lower Cretaceous Dinosaur.

Among some material collected from the Comanche Cretaceous of Clark county, Kansas, several years ago, by Prof. C. N. Gould, there is a nearly complete centrum of a carnivorous dinosaur allied to *Creosaurus* or *Allosaurus*. It measures 100 mm. in length, 87 in transverse diameter at the extremities, and about 100 in height. The ends are vertically oval and nearly flat; the sides and below are deeply concave in outline. The specimen doubtless represents a new form, but the material preserved is too incomplete to furnish even generic characters.

This is, I believe, the second specimen of a dinosaur that has been discovered in the Cretaceous of Kansas, the other being the type specimen of *Claosaurus agilis* Marsh, discovered by Marsh many years ago in the Niobrara Cretaceous of the Smoky Hill valley, in western Kansas.

New Benton Turtle. (Protostega?)

The turtles of the genus *Protostega* have hitherto been known only from the Niobrara Cretaceous of western Kansas, and those of the nearly allied genus *Archelon* from the Pierre of South Dakota. Several years ago a specimen of a large turtle, belonging either to the genus *Protostega* or an allied new one, was collected from a lower stratum of the Benton Cretaceous of Kansas by Prof. W. N. Logan. The specimen consists of some fragmentary ribs and a part of a large humerus, apparently larger than that bone in *P. gigas*. The material does not permit a close comparison, however.

Mosasaurs.

At different times I have expressed a doubt of the validity of the genus *Holosaurus* Marsh as distinct from *Platecarpus*. An examination of the type specimen of the genus has not wholly

dispelled this doubt, but has strengthened my opinion of its invalidity. There is less difference, I believe, between *Holosaurus abruptus* and *Platecarpus coryphæus* than between *Clidastes velox* and *C. dispar*, and especially between the latter and *C. stenops*, mentioned below, forms presenting similar differences to the chief one separating *Holosaurus* from *Platecarpus*.

Holosaurus has no zygosphenes, as I at one time suspected it possessed, nor can I distinguish any difference in the skull as it lies in the matrix with the dorsal surface concealed. It is to be hoped that the specimen may be removed from its matrix at no distant day, and so preserved that all parts may be available for comparison.

There are, however, certain differences in the girdles and limb bones which distinctly remove this species from those of *Platecarpus* hitherto made known. Plate XLI, figs. 2 and 2*a*, of my report upon the Kansas mosasaurs, show the distinctive forms of the pubis and ischium, easily distinguishable from those bones of *Platecarpus coryphæus*. The specimens there figured I found isolated near Monument Rock, and I was never sure where they belonged, though, from their general resemblance to the bones of *Platecarpus*, I referred them to that genus. These differences are seen in the greater expansion of the distal extremity of the ischium, and in the shape of the proximal end of the pubis. The radius figured in plate LVII, figs. 1 and 2, also belongs with this species, distinguishable by the differences in form from that of *Platecarpus coryphæus*. I know of no other bones which may be confidently referred to that species, nor are the differences in other bones at all conspicuous or even perceptible. There is, of course, a possibility that the species *H. abruptus* may prove to be identical with some species of *Platecarpus* described by Cope. Evidence of such identity can only be ascertained by a study of the types.

Clidastes stenops Cope.

At the time of the publication of my report upon the mosasaurs of Kansas, I had never recognized a specimen of this species, of which nothing has been published since its original meager description by Cope. Recently a considerable part of a skeleton, which I refer to this species, has been obtained from Mr. Chas. Sternberg, who collected it in western Kansas. The

specimen consists of the premaxillo-nasals, maxillary, dentary, splenial, prefrontal, palatine, pterygoids, transverse bones, orbitosphenoids, atlas, axis, and a number of the bones of the anterior girdle and limbs. The bones are in good preservation, and throw not a little light, not only upon this species, but also upon the genus *Clidastes* as well. The specimen is large —larger, indeed, than any other Kansas mosasaur except *Tylosaurus dyspelor*. It differs from the type specimen in size, but I cannot consider this of specific value yet. The prefrontal bone, while not complete, is of a very different type from that found in the other species of this genus. It has no horizontal plate extending over the orbits, resembling in this respect the same bone in *Platecarpus* and *Tylosaurus*. The teeth in the mandible and maxilla are remarkable for their large and conspicuous facets, unequaled in any other mosasaur known to me. The pterygoid has but eight teeth, as in species of *Mosasaurus*, while the number in all the other known species of *Clidastes* is from twelve to sixteen. The palatine bone is remarkably small, while the ectopterygoid is large and stout.

The axis shows scarcely a trace of the zygosphene, but Cope figures it as well developed in the posterior vertebræ. The bones of the paddles are characteristic, as they always are in species of this genus. The coracoid, though incomplete, is evidently emarginate, as in *C. velox*. This character was unexpected, and tends still further to involve in doubt its value in the separation of genera. The radius is very broad proximally, and has its two concave borders of nearly equal length, whereas in other forms the radial border is always much the shorter. The ulna is remarkable for its slenderness, resembling a phalanx rather than an epipodial bone. The first bone in the radial side of the carpus, the radiale, has a very narrow free border; the mediale thus is separated from both the radius and the ulna, which is not the case in any other species of this genus known to me. The first metacarpal also, as usual, is distinctive. The sides are less deeply concave than is usual, and the proximal border is widely expanded.

Clidastes stenops brings up the question of the generic characters of the genus in contrast with those of *Mosasaurus*. I have been somewhat skeptical of the value of the characters for several years, and the present species makes me more so. There

seems to be absolutely nothing left except the zygosphenes. The number of pterygoid teeth varies between eight and sixteen. The absence of the coracoid emargination in *C. tortor* prevents its use as a generic character.

So long as there are no indications of a zygosphene in certain species and a well-developed one in others, the character may remain as the sole difference between the two genera; but I suspect that, as in *Platecarpus*, species will be discovered in which this character is rudimentary or incomplete. In such case the genus *Clidastes* must be merged into *Mosasaurus*.

An examination of the type specimen of *Edestosaurus wymani* Marsh discloses the fact that the species is not at all distinct from *Clidastes velox*.

The known Kansas species of *Clidastes* are the following:

C. velox Marsh.
C. dispar Cope.
C. stenops Cope.
C. westii Williston.
C. cinerianus Cope.
C. liodontus Merriam.

The last two are yet very imperfectly known and may be identical with each other; or, it is possible that one or the other is identical with some one of the others.

Orbitosphenoid of the Mosasaurs.

In plate IV, fig. 5, of my report upon the mosasaurs of Kansas (Univ. Geol. Surv., vol. IV), there is given an enlarged picture of an undetermined bone of *Platecarpus*. At the time I could reach no certain conclusion as to its position in the skeleton, and preferred to leave it without comment rather than to guess at its position. In the specimen of *Clidastes stenops* just described, two similar bones, differing only in being a little more slender, were found in the matrix lying upon the axis, and another attempt was made to determine them. That they could not be hyoid bones was certain, since they differed too much from the real hyoid of *Tylosaurus;* nor could they be epipterygoids, bones described by Marsh, but of which I had been very uncertain, since there are no places on the pterygoids and petrosals to admit of their attachment. An examination, aided by Mr. Martin, of the material in the University of Kan-

sas museum, disclosed them in four different skulls. In one the bone lies transversely in the bottom of the supratemporal fossa anteriorly; in another, one was found impressed upon the under surface of the parietal, also transversely. A third was found by the side of the basisphenoid. In the fourth specimen, fortunately, both bones were discovered lying side by side on the under surface of a frontal bone of *Platecarpus*, with the broad or flattened end lying over the two pits or depressions for their attachment. These pits are toward the posterior end of the frontal bone, on the sides of the median line, and narrowly separated by the olfactory groove. They are clearly shown in fig. 3, plate XXVI, as also in plates XII and XV of the above-mentioned work. The other extremity of the bone has not been found in position, but, by placing a well-formed bone in position, this extremity is found to approach or meet the rounded, conspicuous pit on either side of the base of the presphenoid, at the anterior end of the sphenoid, and here is doubtless where it belongs. The bone, as seen in the enlarged figure, terminates below in a cylindrical and truncated extremity, which is either flat or cupped. The other extremity is broad and flattened, with a transverse, curved sutural surface, for lodgment in the frontal pits. The posterior border is deeply concave; the anterior border convex and subangulated near the middle. The inner surface is more flattened than the outer (the one shown in the figure). The two bones lie parallel with each other, almost touching, with only a narrow space between them above for the passage of the olfactory bulb.

Because of this attachment to the frontal bone, it would seem certain that the bone is the orbitosphenoid and not the alisphenoid, especially so if the lower attachment is, as I believe it to be, in front of the optic foramen. However, the same or a similar bone is found among some lizards, though less completely ossified, and with feeble or no attachments. It is called by Cope the "postoptic," provisionally:

"The membranous wall of the brain-case anterior to the petrosal contains an ossification which is of uncertain homology. It reaches or approaches by its superior extremity the frontal, and might hence be supposed to be the orbitosphenoid, but this homology is vitiated by the fact that its inferior portion passes behind the optic foramen. The latter position is that of

the alisphenoid, and so the bone is named by Parker. (Trans. Roy. Soc., 1879, p. 615.) But there is another element, the epipterygoid, posterior to it, and immediately anterior to the petrosal, which has been supposed to be the true alisphenoid.[1] Leaving this question, and adopting for the bone in question the provisional name of postoptic, I remark that it is typically triradiate, sending two branches up and one downward," etc.[2]

In one or two instances I have seen a slender rod of bone in *Clidastes*, which I have thought to be the epipterygoid, but I have never been sure. Marsh[3] described the epipterygoid as a rod of bone in *Platecarpus*, and Osborn also identified it as a flattened rod in *Tylosaurus*. It is strange, however, that it does not appear more frequently in the many skulls of these animals discovered in the Kansas Cretaceous.

Lying by the side of an excellent skull of *Clidastes tortor* in the museum there is a slender rod, with a sharply truncated extremity, whose position in the skeleton I do not know, unless it belongs in the hyoidean apparatus. It is too large and too long to be an epipterygoid. The bone is cylindrical, gradually tapering, with the truncated surface oval.

Platecarpus Species from North Dakota.

In plate XIII is shown an ischium and some paddle bones of a species of *Platecarpus*, recently sent me for examination by Professor Sardeson of the University of Minnesota. The bones were obtained from near Milton, in the northeastern part of North Dakota, enclosed in a blue shale very much like that of western Kansas. Associated with the specimen were others of *Hesperornis*, etc., all evidently belonging to the upper part of the Niobrara Cretaceous. The present specimen differs from any species of *Platecarpus* that I know, in the shape of certain bones, and indicates a distinct species. But I do not know all the species that have been described from the Kansas Cretaceous in this genus, and will leave its determination until further information is forthcoming.

The following notes were made by me after an examination of the type specimens at the Yale museum, two years ago; I

1. This is, however, contested by Baur, because of the presence of both the alisphenoid and epipterygoid in *Sphenodon*.

2. Cope, An. Rep. U. S. Nat. Mus. for 1898, p. 187.

3. Marsh, Amer. Journ. Sci.

have to thank Professor Beecher for permission to examine them:

Lestosaurus gracilis Marsh. The type consists of fragments of the skull and cervical vertebræ. The vertebræ show much compression, as do also the bones of the skull. The fragment of the parietal is normal, the opening rather large. Quadrate somewhat distorted. The specimen is a little smaller than usual. It is apparently identical with *Platecarpus coryphæus*. No. 1264. Three miles east of Fort Wallace, north side of Smoky Hill river, August 31, 1871.

Lestosaurus simus Marsh (*Platecarpus ictericus*). No. 1352. Seventeen miles east of Fort Wallace, south side of Smoky Hill, in blue shale, July 26, 1871.

Rhinosaurus micromus Marsh. South side of Smoky Hill river, November 2, 1872.

Edestosaurus dispar Marsh. North fork (?) Smoky Hill river.

Edestosaurus velox Marsh. "Fossil from Sheridan, Kan., collected by Savage, November, 1870." Marsh's handwriting.

Edestosaurus rex Marsh. Three miles southeast of Fort Wallace, eight feet below top of blue shale, July 10. Is *Clidastes tortor*.

Lestosaurus felix Marsh. Fourteen miles east of Fort Wallace, July 15, E. S. Lane. Is *Platecarpus coryphæus*, apparently, though the sides of the frontal bone show only a moderate emargination.

Hadrosaurus agilis Marsh. Twenty-six miles east of Fort Wallace, north side of Smoky Hill river. Is from the Niobrara, the bones showing the characteristic compression.

Dr. M. Janischewsky[4] figures and describes a bone which he believes to be a mosasaur coracoid from "den untertertiaeren Ablagerungen des Gouv. Saratow." I regret my inability to read the Russian text of his article, but, from the resume and the figures, I hardly think the bone can pertain to a mosasaur. The size would be enormous for a mosasaur—fully twice that of any known species. Though incomplete, the shape of the bone is somewhat unlike that of any mosasaur coracoid known, though the resemblance is evident. It seems to be a reptilian

4. In Ann. Geol. et Min. de la Russe, v, p. 94, 1902.

coracoid, and its discovery in the "grunlich grauen eocenen Glaukenitsande" is remarkable. It apparently does not have the characteristic coracoid foramen. Further information concerning this Tertiary animal will be looked forward to with interest.

In conclusion, I desire to correct an error made by myself. That which I considered the nuchal fringe in the mosasaurs is evidently only the slender cartilaginous rings of the trachea, first described and figured by Professor Osborn. I have no excuse to make for the mistake, which I recognized when too late to correct.

Explanation of Plates XII and XIII.

PLATE XII. Upper figure—Part of hind paddle of *Platecarpus coryphœus* Cope, in matrix one; natural size. Lower figure—Part of front paddle of *Clidastes stenops* Cope.

PLATE XIII. Ischium and part of hind paddle of *Platecarpus* sp., from Milton, N. Dak.

PLATE XII.

PLATE XIII.

ON CERTAIN HOMOPLASTIC CHARACTERS IN AQUATIC AIR-BREATHING VERTEBRATES.

BY S. W. WILLISTON.

In the endeavor to reach more satisfactory conclusions regarding the life habits of the plesiosaurs, the following article was written nearly a year ago, since which time I have received the very interesting and valuable paper by Professor Fraas on the thalattosuchian crocodiles,[1] in which I was pleased to find a similar discussion, in large part anticipating what I have to say here. I venture to publish my observations as extending and corroborating his statements, and have added further details gathered from his paper—details bearing materially on the subject-matter.

Among living and extinct vertebrates there are at least six more or less unrelated groups which have become in part or entirely adapted from terrestrial to aquatic existence—the cetaceans, sirenians, ichthyosaurs, plesiosaurs, and certain crocodiles, to which might be added certain testudinates and rhynchocephalians. The pinniped carnivores show a much less complete transformation from the terrestrial carnassidentia, and are of interest here chiefly by reason of the modifications which the limbs have undergone.

The many structural and phylogenetic differences which these diverse orders present render their many "convergent" or homoplastic features of peculiar interest. These features may be for the most part explained by a progressive adaptation to environment. Wherever food habits and environment have concurred the homomorphic results have often been striking. In other forms, however, where the food habits have been dissimilar, modifications have occurred. And it is in these modifications that I have sought some hints as to the probable habits of the plesiosaurs. The more important adaptive characters of these air-breathing vertebrates seem to be the following. Of course they are not all concomitant, but they are all,

1. Paleontographica, xlix, p. 3, 1902.

I believe, the result of adaptive changes from terrestrial to aquatic life:

Elongation of the head, with attenuation of the facial region.

Elongation of trunk and tail, but especially of the latter, with progressive weakness of the zygapophysial articulations posteriorly.

Shortening of the neck.

The acquirement of a caudal fin.

The presence of sclerotic plates.

Recession of the external nares.

Absence of sacrum and the obsolescence or absence of the sternum.

Greater slenderness and small size or loss of the hind limbs.

Broadening and shortening of the limb bones.

Hyperphalangism and hyperdactylism.

Smoothness of the skin.

Sponginess of the bones of the skeleton, with a larger proportion of organic matter.

Increase in number and decrease in size or loss of the teeth.

In the fish-eating swimming vertebrate, speed and the ability to quickly change the direction of movement must be essential for the welfare of the individual. These have been obtained by such changes in the form of the body as decrease resistance to the water, and by the development of organs to give strong propulsion and rapid evolution. Propelling power may be furnished by large and strong paddles or flippers, but more effective control and power are given by a long and flexible tail with a fin-like termination. In reality, it is found that, as the tail is large and powerful, the limbs, especially the hind ones, lose their propelling power and become organs of equilibration. A large tail and large paddles are not found together. When, as is sometimes the case, the tail is small, the hind limbs take on more the character of guiding or sculling organs than of oar-like paddles, as is probably the case in many pinnipeds.

The elongation of the head and attenuation of the facial portion are best exemplified by the ichthyosaurs, some plesiosaurs, the semiaquatic gavial, and the more aquatic geosaurs, and perhaps, also, by some of the rhyncocephalians—all, probably, with like food habits. Among some of the odontoceti only is there an approach to the reptilian slenderness of the face; an

example of such is the dolphin of the Ganges, a fish-eating cetacean. This type of head is best illustrated in the gar-pike, a surface-feeding fish, whose food consists almost exclusively of small fishes, which are caught by quick movements of the body and jaws rather than by rapid swimming. I doubt very much whether any of the reptiles before mentioned had the ability to move with any great degree of speed through the water.

In the long-necked plesiosaurs the head is broader, flatter, and less elongate, with the teeth larger and more unequal in size. In the mosasaurs the skull is larger, less elongate, though still of a distinctly elongate type, especially in the more specialized forms, such as *Tylosaurus*. The teeth are larger, are less firmly implanted in the jaws, and there are additional teeth upon the pterygoids, wanting in the other aquatic vertebrates. Furthermore, the mandibles have a peculiar lateral articulation; all of which characters indicate larger and more powerful prey. Indeed, remains of fishes of considerable size have been found in the fossilized stomach contents of these animals.

Plesiosaurs, or at least some of the long-necked forms, had the strange habit of swallowing siliceous pebbles, sometimes of considerable size and in considerable quantities; as many as a peck have been found among the remains of a single animal. Seals and crocodiles are said to have similar habits; the reason therefor is hard to conjecture. These pebbles, moreover, were carried in the plesiosaur's stomach until reduced to very small dimensions, indicating clearly the smallness of the pyloric orifice and the complete digestion of the food material. Coprolites, evidently of mosasaurs, are frequently found, with large, undigested fish bones, and fragments of fish bones, and sepia shells have been found in reputed ichthyosaurian coprolites.

The posterior position of the external nares, not only in the cetaceans, but also in the ichthyosaurs, plesiosaurs and parasuchian "crocodiles," is doubtless due to environmental causes. In the mosasaurs the nares are large, but are located anteriorly, though not at the extremity of the snout. Why they should be so small and situated so far back in the ichthyosaurs, plesiosaurs and *Belodon* is not evident.

In all the aquatic reptiles sclerotic plates are well developed. They are present in the plesiosaurs, a fact hitherto published,

though modern text-books still continue to affirm their absence in these reptiles. They doubtless furnished better protection for the eyes under varying pressure, and perhaps aided vision, both of which would indicate that these animals were in the habit of going to considerable depths.

The shortening of the neck is carried to the extreme in the ichthyosaurs and cetaceans, the most specialized of aquatic air-breathing vertebrates. In the mosasaurs there has been a material reduction in the length of the neck and in the number of the vertebræ from the ancestral Dolichosaur-like squamate. A similar reduction in length and in number (seven) is also found in the thalattosuchian crocodiles, according to Fraas. Among the plesiosaurs there is extraordinary variability in the length of the neck and in the number of the vertebræ. In such forms as *Elasmosaurus*, from the Pierre Cretaceous, as many as forty vertebræ are credited to the cervical region, and the most of them of an elongated shape. In *Dolichorhynchops*, on the other hand, there are not more than twenty vertebræ in the same region, and all are very short. Both types may have been contemporaneous in the latter time of the plesiosaur's existence. How far the correlation of short neck and elongated skull obtains in this order I do not know, but I believe that such is the rule. I can conceive of no terrestrial form with so extraordinary a neck as have some of the plesiosaurs, and the conclusion is unavoidable that there has been an actual increase in the number, even as it is certain that there has been an increase in the number of vertebræ in the more modern snakes. It is also evident that there has been a decrease in number from the long-necked to the short-necked plesiosaurs. Perhaps in no other order of vertebrates has there been such great variability in the number of cervical vertebræ as in the plesiosaurs.

The elongation of the trunk is constant in the more specialized aquatic types, and there is in such a progressive weakness or obsolescence of the zygapophysial articulations posteriorly, giving greater freedom of movement laterally. The elongation of the tail and the development of a distal fin are correlated with the weakness or absence of the hind limbs, as fins or paddles. In the mammals the fin is placed horizontally, more for the purpose of deep-sea diving than for speed or quickness of evolution, which are needed in but few of these animals. In

Ichthyosaurus and *Geosaurus* the downward curvature of the distal caudal vertebræ gave support to the lower side of the caudal fin. In the mosasurs the tail is not decurved, and the dilatation was evidently not terminal but along the distal part. In the plesiosaurs the tail is never greatly elongated, and in some was probably short. There was, however, a terminal, fin-like dilatation, and, in some forms at least, the distal caudal vertebræ were curved upward.

The tendency toward a metamorphosis of the ambulatory into natatory limbs is constant; it is always more pronounced in the anterior than in the posterior extremities. In the cetaceans and sirenians the hind limbs have disappeared entirely in the living forms, though the earlier, extinct sirenians were also provided with hind extremities. In the ichthyosaurs the hind limbs are always decidedly smaller than are the front ones, while in the mosasaurs a similar, though less pronounced, weakening of the hind limbs is evident, particularly in the more specialized groups like the Tylosaurinæ. Among the plesiosaurs the hind extremities are always powerful and well developed, though in all the forms known to me they are less powerful than the front ones. Here the relative shortness of the tail has imposed a distinct propelling or sculling function upon the hind limbs, as is the case to a much greater degree among some of the pinnipeds. In *Geosaurus*, on the contrary, the hind limbs are larger than the fore limbs, while the tail is elongated and provided with a terminal fin, evidently of no small size. But these legs in *Geosaurus* were distinctly ambulatory and of little use in the water; they were doubtless carried close to the tail in swimming, as in the partly metamorphosed tadpole.

Hyperphalangism is best exhibited in the cetaceans, ichthyosauria, and plesiosauria; and in the ichthyosaurs there is hyperdactylism also. With our present knowledge, it would seem remarkable that serious argument was needed to controvert Gegenbaur's views as to the ichthyic affinities of the paddles in these animals. Among the mosasaurs hyperphalangism is more pronounced in the more specialized *Tylosaurus* than in the other groups. While in *Mosasaurus* the fifth digit has been lost in the hind foot, and in other forms is reduced in size, inherited terrestrial characters, in *Tylosaurus* the fifth toe has become greatly

elongated, and its phalanges increased in number commensurate with those of the other digits.

With hyperphalangism has occurred also a shortening of the limb bones, especially those of the front pair, which are the first to show natatorial characters. There has also occurred a restriction of articular movement, with imperfect joints. Those ichthyosaurs (*Mixosaurus*) and plesiosaurs (*Plesiosaurus*) which have preserved an elongated form of the epipodial bones are clearly more generalized than those in which the bones have become mere polygonal platelets, a contestation long ago made by Baur in support of the terrestrial derivation of the ichthyosaurs. Concurrent with such changes is the presence often of three or even four elements in the epipodial series. The attempt to correlate these with mesopodial elements of the terrestrial vertebrate is, I believe, futile. Accessory, sesamoid, mesopodial, or whatever they may be called, they are in reality new growths, like the sixth and seventh digits of the ichthyosaur paddle, or the supernumerary digits of the human hand or foot, and not misplaced carpals and tarsals. It would not surprise me greatly to learn of plesiosaurs with additional digits.

In *Geosaurus* there is a distinct beginning of the aquatic paddle in the fore limb, although there is scarcely any change from the ambulatory limb behind. As an example of a stage through which probably all other aquatic vertebrates have passed, the thalattosuchia are very instructive. In those aquatic lizards, the mosasauria, we find a more advanced stage, with shortening of the bones and hyperphalangism more or less pronounced, but the widely spreading digits, the relatively large size of the hind limbs, the presence of a sternum in the more generalized forms at least, and the less elongated head, are all indications of a lesser specialized stage than is seen in the cetaceans, ichthyosauria, and plesiosauria.

In the cetacea and sirenia, the sternum, though reduced, is not entirely lost, nor is it lost in the mosasaurs, at least in the more generalized groups. It has not suffered in the aquatic crocodiles, but in the ichthyosaurs and plesiosaurs it has vanished utterly. The sacrum is wanting in all the true aquatic types. No longer needed for the support of the body in ambulation, the united vertebræ, with rigid or close union with the ilium, must have interfered with free movements of the

body, and its loss was to be expected In *Geosaurus*, with its ambulatory hind limbs, the sacrum has not disappeared. The ilium, where present, is small, merely a connecting rod, united by ligament to some transverse process. In the mosasaurs it is directed forward from the acetabulum; in the plesiosaurs, on the contrary, its position is upward and backward.

Why the pectoral and pelvic girdles should have been so remarkably developed on the under side of the body in the plesiosaurs is not clear, forming, as they do, a nearly complete, convex, bony armor on the under side of the trunk, supplemented by the abdominal ribs. In the ichthyosaurs, with the less broad expansion of their girdles, the more numerous ventral ribs may have served a similar end. Abdominal ribs are found in the crocodiles, but there are none in the mosasaurs.

It is a remarkable fact that in all aquatic vertebrates, except the bottom-feeding sirenia, and the ichthyosaurs, of which I can get no information, the bones of the skeleton have become more cancellated and spongy. The oily character of the pinniped bones is well known, as also the great sponginess of the cetacean bones. Among the plesiosaurs a similar soft and friable structure of the bones is painfully evident, and in the mosasaurs there is a very distinctly greater softness and sponginess of the bones in the more specialized types.

Nakedness of the skin is of course to be expected among swimming animals; hair has almost disappeared in the mammals, and scales or plates in the reptiles; in the mosasaurs alone scales are still persistent, but they are relatively small and smooth.

It is very evident that the plesiosaurs were not quick-swimming animals; the body was relatively broad, flat, and thick-set, very unfish-like in form; the paddles were small as compared with the size of the body, and the tail was not of sufficient capacity to compensate for their incapacity. The more or less elongated neck—for in none was the neck short in the sense of the ichthyosaurs—did not give any advantages in movement. The movements of these animals must have been more like those of the turtles than of the mosasaurs or crocodiles. The head was relatively small, and the narrow gullet, between unyielding bones, permitted the deglutition of small animals only—very small indeed as compared with the size of the body. The spongy structure of the bones clearly indicates that they were

not bottom feeders, like the sirenians. At the same time they must have traveled or migrated long distances in the water. The siliceous pebbles, so often found with their remains in the Kansas chalk, could only have been obtained hundreds of miles away, for they are absolutely unknown away from the remains of these animals.

The ichthyosaurs are known to have fed upon cephalopods and other invertebrates, if the coprolites ascribed to them are really ichthyosaurian. I believe that the plesiosaurs, or many of them, fed largely upon such food, living along the shores in comparatively shallow water, and were not accustomed to go to considerable depths; that is, they lived for the most part near the surface of the water. Evidence presented by Seeley years ago seems to indicate that they were viviparous in habit like the ichthyosaurs, though such evidence has not been forthcoming in America. It is a singular fact that embryonic propodial bones of plesiosaurs are not at all rare in the Kansas chalk. There are five such bones in the Kansas museum collection, and I have seen perhaps a score of others. These bones are always found isolated, and were for a long time very problematical. In some, the peculiar epiphysial structure is beautifully shown. In all, there are several foramina perforating the middle, with a groove leading therefrom corresponding to the ent- or ectepicondylar groove of the testudinates and mosasaurs. The conical 'epiphyses' terminate at these canals.

"Entsprachen die soeben gegebenen Ausführungen den Thatsachen, so kann man sich die Plesiosaurier auch nicht länger als auf der Oberfäche des Meeres, etwa wie Schwimmvögel lebende Geschöpfe vorstallan, sondern sie haben, wie die Ichthysaurier, unter der Oberfläche im Meere gelebt."[2]

This conclusion of Dames I have no doubt is correct. His restoration (l. c., p. 79), I believe, is somewhat faulty in the two angular caudal expansions and in the pedunculation of the limbs. I believe the latter were broader proximally, as was certainly the case in both the ichthyosaurs and mosasaurs.

It is evident from the great variations in form among the plesiosaurs that they varied not a little in habits. Though exceeding in size the largest mosasaurs, I do not think that they were ever a match for them in prowess or voracity. Like the gavials, they were comparatively harmless creatures.

2. Dames, Abh. Konigl, Preuss. Akad. S. Wissensch., 1895, p. 79.